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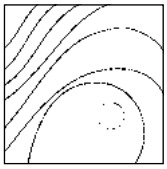
Unconventional Implants for Distal Cantilever Fixed Full-Arch Prostheses: A Long-Term Evaluation of Four Cases



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Excessive cantilever lengths of fixed implant-supported prostheses may have functional and biomechanical disadvantages. This study reports the clinical outcomes of unconventional implants placed for distal support of a fixed implant-supported prostheses. Seven extraoral implants with intraosseous lengths of 2.5 to 4.0 mm were placed in four patients. Distal cantilevers had a mean length of 29.8 mm (range, 18.6 to 39.3 mm). No bone loss or other adverse events were found. The prosthetic plan was maintained in all patients. Within the limits of the employed research design, this concept seems to be a successful option for fixed complete implant-supported prosthesis treatment. (Int J Periodontics Restorative Dent 2012;32:e59–e67.)

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In the prosthodontic treatment of the edentulous mandible, both fixed and removable implant-supported prostheses usually can be offered. Still, the precise number and distribution of implants is determined by more specific individual characteristics, such as anatomical and morphologic conditions.[1] A fixed cantilever prosthesis is favored by a distinct anterior curvature, whereas implants placed in a straight anterior line may result in a biomechanically unfavorable situation for loading and therefore shortened dental arches.

Initially, four to six implants between the mental foramina were recommended to support an implant-anchored fixed prosthesis in the treatment of complete edentulism.[2,3] Fixed cantilever implant-supported prostheses were demonstrated as a predictable clinical protocol and have been applied successfully for more than two decades.[4–6] The fixed cantilever prosthesis is designed to reach first molar occlusion, so patients receive a fixed prosthetic rehabilitation of 10 to 12 teeth.[7–9] Whenever possible,

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implants for full-arch fixed partial dentures are evenly distributed over the entire dental arch to avoid long cantilevers.

An implant-supported prosthesis with bilateral distal cantilevers offers the advantage of being fixed, but also has functional and biomechanical disadvantages. Approximately 50% of patients with cantilever fixed prostheses report complications in the long term.[8] Heavy occlusal loading and undesirable distribution of occlusal contacts may result in overloading, with possible higher susceptibility to implant and prosthetic failures.[10] The magnitude of strain is likely different under conditions of a curved arch form, as opposed to implants placed in a straight line.

Implant overloading can be attributed to clinical complications such as screw loosening or fracture, fracture of the veneering materials, prosthesis and implant fracture, as well as implant loss.[11–14] Fractures of the resin or veneering material were the most frequent prosthesis-related complications reported[8,9,15] and were associated with the deformation module of the framework.[16] Excessive cantilever length was reported among the possible causes for prosthesis failure because of framework fracture at the beginning of the cantilever arm.[8,10,17]

Several modifications of conventional occlusal concepts have been proposed to reduce occlusal force on implant prostheses, including increasing implant surface areas and reducing the length of the cantilever in the mesiodistal and buccolingual dimensions.[11–14,18] Furthermore, adding more implants was also recommended.[19]

Additional implant placement on each side distal to the mental foramen was suggested to improve masticatory efficiency, avoid prosthetic complications, and improve patient satisfaction.[20] This treatment modality is sporadically reported in the literature, and mainly used underneath a cast metal removable denture.[21–25] Komiyama[20] reported excellent results using one or more additional implants to support an implant-supported fixed complete denture when enough bone was available on each side of the mental foramen. Miyamoto et al,[26] however, demonstrated that this treatment modality worsened the prognosis of posterior implants ≤ 10 mm in length.

The demand for short implants has increased in situations where available bone is limited, to avoid additional surgery, to simplify the treatment, and to reduce costs. Previous studies have demonstrated that roughened surface implants ≤ 8-mm long can be successfully applied to support complete fixed prostheses, preferably in combination with longer implants.[27–29] More recent publications showed that placement of 5- and 6-mm-long implants in the posterior areas restored as individual crowns or to assist fixed partial dentures could demonstrate favorable results when compared to longer ones.[30–33] However, the treatment may be more demanding in situations where even short dental implants cannot be used without an additional surgical procedure.

The aim of this study was to evaluate fixed full-arch implant-supported prosthesis treatment using the additional support of short, unconventional implants. Implant success rates as well as complications with implant components and suprastructures are presented over an observation period of 5 years.

Method and materials

Included patients were those referred for the treatment of an edentulous mandible to the Pyramid Clinic, Zurich, Switzerland. Inclusion criteria for all patients consisted of good local and systematic health and absence of oral disease and alcohol or drug abuse. Good hygiene maintenance was requested, and those without history of radiation therapy in the head and neck region were included in the treatment. Panoramic radiographs (Orthophos CD, Siemens) and diagnostic casts and wax-ups were obtained for all patients. Patients presented edentulous U-shaped mandibles with ≤ 6 mm of available bone height in the posterior region. Each patient signed a written consent form.

Surgical procedure

All patients received perioperative medication (Bactrim forte 1 g two times daily, Roche Pharma; augmentin 625 mg three times daily, GlaxoSmithKline; and Dalacin C 300 mg three times daily, Pfizer) and 0.12% chlorhexidine digluconate

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mouthrinse (30 seconds). The surgical procedure was performed in all patients by the same surgeon under local anesthesia. Roughened implants were placed under aseptic conditions using sterile irrigation with a contra-angle handpiece. Healing caps were placed, leaving the implants in a transmucosal position.

Extraoral sandblasted, large-grit, acid-etched implants (Straumann) with self-cutting threads were placed. The neck of the implants was either 3.5-mm (conical) or 5-mm wide (shoulder type), with an implant body diameter of 3.3 mm. The intraosseous portion was 2.5, 3.5, 4.0, or 5.0 mm in length. Implant length was determined according to a 1-mm safety margin above the mandibular canal, as measured on orthopantomographs.

An osteotomy was performed using a corresponding single Straumann profile handpiece to the final depth. Extraoral implants were inserted by hand using a wrench until the shoulder reached full contact with the bone. Healing caps were inserted with a torque of 15 Ncm, implants were left submerged, and the wound was closed.

Postoperatively, antibiotics were prescribed for 5 days, 0.12% chlorhexidine mouthrinse for 14 days, and analgesics were to be used when necessary. Sutures were removed 10 to 14 days after surgery. Provisional prostheses were not to be used during the first 14 days or were generously relieved from direct contact with the implants.

Prosthodontic treatment

Extraoral implants were uncovered after a healing period of 4 to 6 months, and transcutaneous healing caps were inserted. After 7 to 10 days, standard screw-retained synOcta transfer impression copings (Straumann) were mounted on the anterior implants. Impression cylinders or Titanmagnetics impression caps (Straumann) were screwed onto the extraoral implants. An impression was taken with an elastomeric impression material (Impregum Penta, 3M ESPE) using an individual tray and removed with the transfer copings in situ. Standard synOcta implant analogs or conical or Titanmagnetics model implants (Straumann) were positioned, and the casts were poured in a hard type 4 plaster. The abutments were selected in the laboratory with the aid of a diagnostic planning kit while taking into account the interocclusal space.

The cast framework was tried intraorally to check the fit of the framework, the vertical dimension, and occlusion. Full occlusion was maintained in all cross-arch fixed partial dentures, following a balanced occlusal scheme. Occlusal contacts were distributed evenly on all teeth including teeth used as cantilevers. Abutments were tightened with a torque of 35 Ncm on the anterior implants and 15 Ncm on the extraoral implants. After esthetic evaluation and occlusal adjustment, the suprastructure was screwed onto the anterior abutments with a torque of 15 Ncm. Minor adjustments were needed to achieve maximal occlusal contacts and bilaterally balanced group function in articulation.

The distance from the most distal aspect of the extraoral implant and the end of the cantilever was measured on the panoramic radiographs using Sidexis XG version V1.6 software (Sirona).

Success criteria

Patients were enrolled in regular monitoring with clinical and radiologic evaluations. Follow-up visits were scheduled for 2 weeks; 3, 6, and 12 months after prosthesis delivery; and annually thereafter. Panoramic radiographs were taken at all recall appointments after the postsurgical phase and annually thereafter.

Implant success was defined according to the proposed criteria[34–36] followed at each recall, which included absence of perceptible implant mobility; absence of complaints such as pain, dysesthesia, or paresthesia; absence of recurrence of peri-implant infection and suppuration; and absence of continuous radiolucency at the implant-bone junction. The peri-implant bone level around extraoral implants was additionally determined by measuring the distance between the implant shoulder and the first crestal bone–to-implant contact, and classified according to a 4-point rating scale: no apparent bone loss (0), bone loss not exceeding more than one-third of

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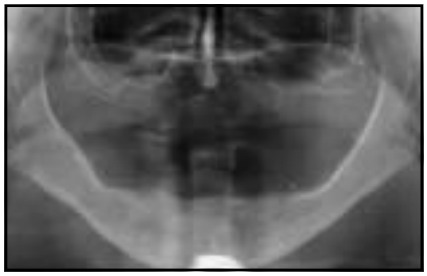

Fig 1a *Preoperative panoramic radiograph showing the minimal bone available superior to the inferior alveolar canal in the edentulous molar region.*

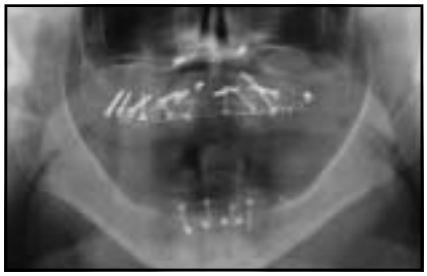

Fig 1b *Panoramic view of the maxilla and anterior mandible augmented with autogenous bone graft from the iliac crest.*

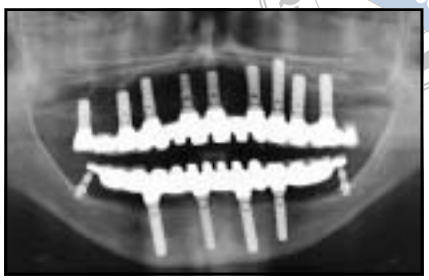

Fig 1c *Panoramic radiograph showing a fixed full-arch prosthesis in the mandible supported by four anterior implants and two extraoral implants at the second molar sites, both 2.5 mm in length.*

Table 1 Patient and implant characteristics

Patient	Age (y)	No. of dental implants	Extraoral implants		Cantilever length (mm)	Follow-up (y)
			Length (mm)	Abutment		
MB	63	6	2.5	Magnet	18.6	9.0
ME	44	7	2.5, 2.5	Conical cylinder	31.3, 34.2	9.0
AM	54	4	2.5, 2.5	Conical cylinder	25.3, 26.9	8.0
NH	60	5	4.0, 4.0	Conical cylinder	39.3, 33.2	6.5

the implant length (1), bone loss exceeding more than one-third of the implant length (2), and bone loss exceeding more than one-half of the implant length (3).[37] Patients were evaluated for technical complications related to the implants (healing abutments, screw loosening, or fracture) and prosthesis (fracture of tooth, porcelain, or metal framework).

Results

Four women (mean age, 55.3 years) were included in the study. In one patient, bone was harvested from the iliac crest before implant placement for simultaneous augmentation of the maxilla and anterior mandible (Fig 1). From a total of 22 dental implants placed in four patients, 18 were Straumann (Straumann) and 4 were Nobel-Replace (Nobel Biocare). The mean length of the implants was 14.5 mm (range, 10 to 16 mm). In the maxilla, all patients received a fixed full-arch prosthesis.

The first patient treated received one extraoral implant at the second molar site on the left side while the distal implant on the right side was placed at the first molar site. The three other patients received one extraoral implant at the second molar site on each side. All extraoral implants were shoulder type, with a mean intrabony length of 3.2 mm. Details are given in Table 1.

Implants were restored after a mean healing period of 4.3 months. At exposure, all conventional implants resisted the removal torque of 35 Ncm and extraoral implants of 15 Ncm, as recommended by the manufacturers. The patients were provided with cast gold alloy frameworks and porcelain-fused-to-gold screw-retained prostheses. In one case, two extraoral implants were restored with abutments specially fabricated by the manufacturer (Straumann), corresponding to conventional implant abutments

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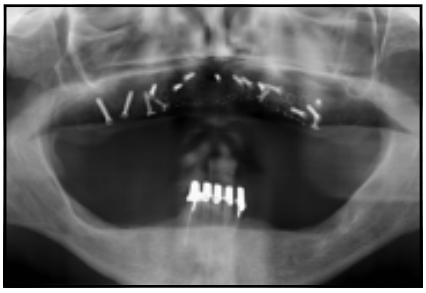
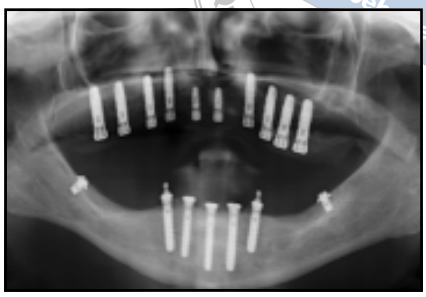


Fig 2a (left) *Preoperative panoramic radiograph showing the maxilla augmented with autogenous bone graft from the iliac crest and the minimal bone available superior to the inferior alveolar canal.*

Fig 2b (right) *Radiologic appearance of five dental implants and two extraoral implants placed at the mandibular second molar sites, both 4 mm in length. Two distal dental implants were initially placed before tooth extraction and restored with ball anchors for removable prosthesis support during the healing phase.*



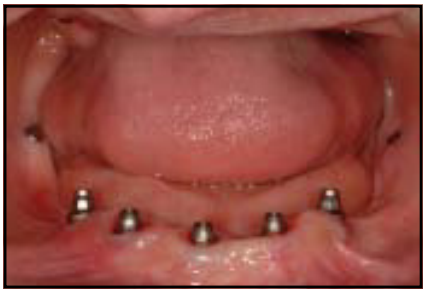


Fig 2c *Clinical appearance of the abutments on five anterior implants and two extraoral implants with transmucosal healing caps.*

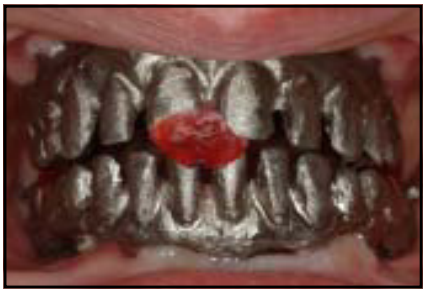


Fig 2d *Gold alloy frameworks in situ with an occlusal stop. Frameworks were cast in one piece.*

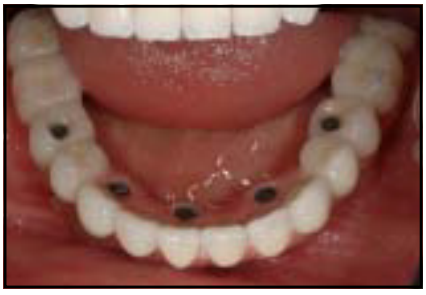
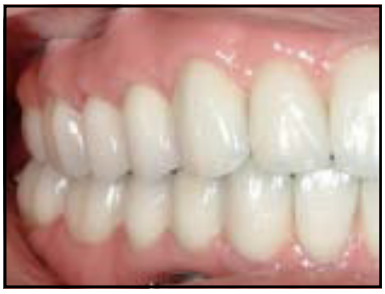
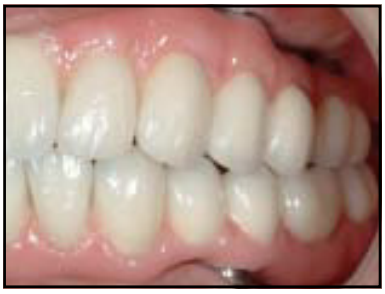


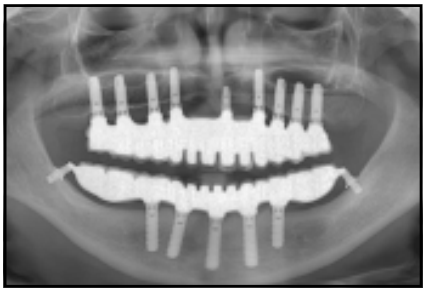
Fig 2e *Definitive restoration with porcelain-fused-to-gold screw-retained prosthesis in situ. Access holes for screw retention are visible.*





Figs 2f to 2h *Esthetic result. Maxillary fixed prosthesis supported by 10 implants matches the esthetic appearance of the fixed prosthesis supported by 5 dental implants and 2 extraoral implants in the mandible.*

Fig 2i (right) *Panoramic radiograph showing the definitive restoration.*



for cement-retained crowns and fixed partial dentures (Fig 2). All extraoral implants were solely used as vertical supports for the distal crown and were disconnected from the restorations. The distal cantilever in the first patient had a length of two crowns, whereas the other three patients had cantilevers

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of three crown lengths. The mean cantilever length was 29.8 mm, with a range of 18.6 to 39.3 mm.

No failures of conventional or extraoral implants occurred during the entire treatment period, resulting in an implant survival rate of 100%. The prosthetic plan was maintained in all patients, and no denture had to be remade. There was no evidence of bone loss ≥ 1 mm around the dental implants or detected bone loss around the extraoral implants (grade 0). No damage to the surrounding vital tissue was found, and no cases of infection, soft tissue irritation, or neurosensory changes were noted.

Discussion

Fixed cantilever cross-arch implant-supported prostheses have been used successfully in the treatment of complete edentulism, with few major problems in the long term.[38] Still, implant placement is confined to the first or second premolar region because of the anatomical limitations of the mental foramina. The morphologic conditions, curvature, and shape of the ridges will additionally determine the distribution of implants and type of prosthesis. In this study, patients presented little or no residual posterior alveolar ridge, where even short dental implants could not be used without an additional surgical procedure. The purpose of this study was to present an alternative treatment modality for patients in whom anatomical restrictions limit the use of implant-based prosthodontic rehabilitations.

Short implants offer the advantage of being a less invasive treatment alternative to implants with longer dimensions.[39,40] Several studies have demonstrated that the use of short implants did not compromise the long-term success of partial[30,32,41,42] or complete fixed dentures.[28,29] As reported in bibliographic surveys, there is a tendency for short implants to fail even before prosthesis placement.[43,44]

Osseointegration is strongly related to the amount of compact bone, which provides primary stability at the time of implant placement.[6,35] Miyamoto et al[45] further demonstrated that initial implant stability at the time of implant placement depends more on cortical bone thickness than the implant length. An adapted surgical protocol is thus necessary to obtain primary stability in sites of poor bone density, with ≤ 3 mm of initial bone height.[31,46] In contrast to trabecular bone, cortical bone of the mandible provides sufficient primary stability for the osseointegration of short, unconventional implants, such as those used in the present report.

Apparently, vertical load of the distal extensions did not jeopardize successful osseointegration of unconventional implants anchored ≤ 5 mm in cortical bone. Previous studies demonstrated that short dental implants resist compressive forces favorably.[47–49] Induced axial loading is beneficial for implant prostheses because of its gradual distribution along the implant-bone interface.[50] A flat contact area directs the occlusal forces in an apical direction, decreasing from the coronal aspect to the apex of the implant.[48] Still, extraoral implants cannot be claimed as functionally loaded, as conventional implants can. A bilaterally balanced occlusion has been successfully used for full-arch fixed prostheses with an opposing complete denture and group function for an opposing natural dentition, but they must both be avoided on cantilevers.[1,10] It was found that occlusal and masticatory forces decreased distally along the cantilever when occluding with fixed dentures.[18,51] Increased distal forces seen for complete dentures may be explained by displacement during function. Although disconnected from the restorations, extraoral implant support permitted cantilevers stretching to the second molar region, beyond the suggested limit of 15 to 20 mm.[17,52–54]

Increased cantilever length resulted in a higher load on the distal implant; the relationship between cantilever length and maximum strain is linear.[55] Because of a cantilever effect, the distal implant bears compressive forces and bending moments at least double that of the applied load.[56] More reported framework fractures were related to the early laser-welding technique in comparison to one-piece titanium and gold alloy frameworks.[8] More recently, Gallucci et al[9] found no clear trend between the type or number of complications and increased cantilever length (18 to

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21 mm). At a cantilever length of ≥ 20 mm, the strain expressed at the bone may be excessive and potentially result in complications and prosthesis failure.[55] Apparently, extension of the cantilever over extraoral implants did not jeopardize treatment success in the present cases.

Besides the length of the cantilever, the distribution of forces may be influenced by a variety of factors, including bone quality; number, distribution, and inclination of implants; design and rigidity of the prosthetic suprastructure; and functional jaw deformation.[56] Despite considerable individual variations in patients, the number of implants seems to play a significant role.[56] An additional implant placed beneath a cantilever extension of a fixed partial prosthesis significantly lowers stress values.[21,57] It is to be expected that extraoral implant support reduces cantilever torque to anterior implants.[58] A recent biomechanical model analysis[59] demonstrated that posterior implant placement under a cantilever fixed partial denture closer to the second molar site may establish stabile occlusal support, decrease the amount of strain, and prevent bone resorption.

Additional posterior implants may reduce cantilever torque to the anterior implants, but posterior implants with rigid attachment could be subjected to stress-induced microdamage.[58] The mandibular flexure phenomenon was thought to be the most likely cause for the 40% failure rate of posterior implants in a study by Miyamoto et al.[26] These cantilevers were cut at 20 mm from the distal implant, whereas the authors recommended splitting of the prosthesis into two fixed partial dentures to reduce the stress over the implants.

The relative movements of the mandible may also demonstrate wide variations from subject to subject.[60] Recent finite element analyses on the stress distribution indicated that bone quality may play a critical role. For the bone qualities investigated, cortical bone was more resistant to deformation than trabecular bone.[61] Having a higher modulus of elasticity, variations in the stresses and strains in trabecular bone were large, whereas those in cortical bone were small.[62] Still, the changes in distance between implants during various mandibular movements are more prominent in the molar than in the premolar region.[63,64] Although none of the implants in the present cases failed, it is questionable how a rigid connection on extraoral implants would affect the implant survival rate.

The use of implants in severely resorbed mandibles and the selection of a reconstructive procedure to facilitate placement of longer implants is still the subject of discussion.[65] New procedures that require different instrumentation and technical skills are often associated with learning curves. The use of unconventional implants in an elderly patient population may be justified because it is simple, not time-consuming, and has a low associated morbidity.

The method applied in the present study may extend the clinical application of implants in the severely resorbed posterior alveolar ridge environment. Four patients were successfully restored in the mandible in the long term, but the results are still inconclusive and should be interpreted with caution. A limited experience in situations involving anchors disconnected to unconventional implants should be confirmed in a prospective clinical trial.

Conclusions

This study promoted the use of additional unconventional implants with a length of ≤ 5 mm in areas previously considered unsuitable because of insufficient vertical bone height. The extension of the fixed cantilever denture is thus allowed to reach second molar occlusion. With careful preoperative planning, this simple strategy seems to be a beneficial and successful treatment option for fixed cross-arch implant-supported dentures.

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